

**Color Gamma Ray Camera  
Laboratory Directed Research & Development (LDRD)  
FY 95, Final Report**

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**Color Gamma Ray Camera  
Laboratory Directed Research & Development (LDRD) FY 95**

**Final Report  
Tracking Code: 94-DI-005**

**Richard M. Bionta, Principal Investigator**

## **Introduction**

Gamma-Ray imaging is a potentially powerful tool for the areas of arms-control, counter proliferation, safeguards and forensics. Combining spectral and spatial information increases the amount of information available for the detection and characterization of Special Nuclear Material (SNM). Two advanced gamma ray imaging technologies have been completed and are nearing completion at LLNL. These include the Gamma Ray Imaging System (GRIS), used to detect sub-600 keV gamma rays, and the Gamma Ray Bar Imaging Telescope (GRABIT), which extends the work of GRIS to larger areas and higher energies (~1000 keV). We proposed to continue work on a third, complementary type of detector, a Gamma Ray Color Camera (GRCC), which will incorporate spatial and spectral information from a gamma emitter.

The need for spatial gamma ray imaging is several fold:

- The ability to spatially resolve the source structure, which allows one to obtain a warhead count, without the need for physical access to the warheads.
- In disarmament, the ability to monitor stored warheads, including their spectral and spatial signatures.
- In safeguards, tracking the SNM into and out of declared nuclear sites, and confirming the nonexistence at undeclared nuclear sites.

An experimental effort was undertaken in the Physical Sciences Advanced Technology Program to develop a color gamma ray camera (CGRC), for the purpose of locating kilogram quantities of SNM. In its final configuration, this detector is designed to show 11 mRad angular and 10 keV energy resolution. It is also meant to show 90% quantum efficiency over the energy range of 0.5 to 3.0 MeV, the upper energy limit exceeding the expected passive gamma radiation from SNM, its decay products and/or contaminants, and from primordial nuclides and their radioactive progeny. The detector concept calls for many layers of resistive plastic with high voltage and signal lines embedded. A particle detector gas is introduced between the detector planes. Compton scattering is the most likely interaction in the plastic; in this detector the resulting Compton scattered electrons are tracked. The incoming photon direction and energy are reconstructed from electron energy and direction information from two or more Compton interactions. The low-cost plastic sheets and the use of reel-to-reel plastic lamination and processing techniques in principle allow very large area detectors to be constructed. The

large area is needed to capture the small number of gamma ray photons expected from certain classes of warheads containing SNM at distances of order 100 m. In FY 94 we fabricated several single gap detectors with different metal sensing geometry's for developing fabrication and electronic readout strategies. We also fabricated multi-gap imaging detectors to demonstrate a directional energy dispersive gamma ray detector. We built a cosmic ray tower including gas system, scintillator trigger, 3 single tracking RPC's, 1 test RPC, and 128 channels of borrowed electronics.

### **FY 95 Objectives**

The primary objective during FY 95, was to continue the efforts listed above leading to the fabrication and testing of a 30 layer/128 channel detector.

Specific tasks were as follows:

- 1.0- Upgrade the real time data acquisition software
- 2.0- Implement 480 equivalent channels of FASTBUS equipment for further prototyping.
- 3.0- Transfer reconstruction algorithms to SUN/UNIX platforms and develop standard output files from the simulation code, the data collection code, and the reconstruction code.
- 4.0- Work with safeguards staff taking HPGe background data and reduce their raw data for input to our simulation codes.
- 5.0- Continue working with commercial manufacturers and suppliers of feed materials for large scale production of sensing layers.
- 6.0- Continue simulations of "real world" scenarios.
- 7.0- Continue investigations of detector response vs. gas mix.

Detectors of this type are traditionally operated with a gas mixture consisting of approximately 40% Isobutane, 4 % Freon 13B1 and the balance Argon. The immediate problem with this mixture is that the Freon 13B1 will not be available because of environmental concerns. In fact Matheson Gas Inc., a leading supplier of specialty gases, plans to stop the manufacture of Freon 13B1 in 1995. Starting in FY 95 we must now pay an additional "ozone depleting" tax of \$48 per pound for F13B1. We must find a suitable replacement for Freon 13B1.

### **FY 95 Progress**

Task 1.0 - The data acquisition software was upgraded to automatically cycle through voltage settings and make summary plots of detector efficiency, noise, and spatial resolution.

Task 2.0 - The 500 channel fastbuss hardware was assembled and electronically verified. Software for utilizing the fastbuss remains to be written.

Task 6.0 - We refined simulations of detector response by incorporating more accurate low energy electron scattering and range models. The results of these simulations underlined the need for very thin plastic layers to maintain

gamma ray energy and angular resolution. Fabricating such thin layers of plastic and assembling them into a multilayer detector appears to be a major technical challenge that requires development. Current plastic fabrication techniques are capable of producing layers thin enough to result in 100 mRad angular resolution for 1 MeV gamma rays.

Task 7.0 - The new acquisition software was used in conjunction with tests of substitutes for the Freon in the gas (task 7.0). In FY 95 we found that SF<sub>6</sub>, a gas used in high voltage applications to suppress spontaneous discharge, performed well as a substitute for Freon 13B1 at similar concentrations. The results of task 6.0 indicate that considerable technical development on the detector is required to demonstrate gamma ray imaging with sufficient resolution for counterproliferation. Much of the basic initial technical development needed for gamma ray imaging parallels similar work funded by the B-Factory LDRD. Further progress on the gamma-ray color camera for counterproliferation should wait the results of the B-Factory efforts on these fundamental detector issues. FY 95 work on the Color Gamma Ray Camera was halted in May 1995 after expending \$26K.

### **Project Abstract**

We proposed to complete the Gamma Ray Color Camera (GRCC) prototype which was begun in FY 94, to demonstrate its utility for counterproliferation by measuring its energy and spatial resolution, and by imaging representative sources in the field.

### **Major Accomplishments and Results - FY 95**

We accomplished the following:

Task 1.0 - The data acquisition software was upgraded to automatically cycle through voltage settings and make summary plots of detector efficiency, noise, and spatial resolution.

Task 2.0 - The 500 channel fastbuss hardware was assembled and electronically verified. Software for utilizing the fastbuss remains to be written.

Task 6.0 - We refined simulations of detector response by incorporating more accurate low energy electron scattering and range models. The results of these simulations underlined the need for very thin plastic layers to maintain gamma ray energy and angular resolution. Fabricating such thin layers of plastic and assembling them into a multilayer detector appears to be a major technical challenge that requires development. Current plastic fabrication techniques are capable of producing layers thin enough to result in 100 mRad angular resolution for 1 MeV gamma rays.

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